Expedited Methods for Assessing and Mitigating Physical and Chemical Hazards at Abandoned Mine Sites

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Introduction

Fort Irwin and the National Training Center (NTC) in San Bernardino County, California, are used to train United States (U.S.) Army brigade-sized units in a realistic battlefield environment. Because of changes in training requirements caused by new equipment, technology, and Army fighting doctrine, the facility was expanded by approximately 110,000 acres (44,517 ha) through a Congressional land withdrawal action in 2001. Further refinements, based on land surveys and GIS analysis of the boundary, indicate the total land withdrawal area to be approximately 118,674 acres (48,012 ha). The newly acquired land resides in one of two extensions to the NTC: the East Gate Expansion Area and the Western Expansion Area.

The legislation expanding the size of Fort Irwin required that the Army comply with the Endangered Species Act, the National Environmental Policy Act, and any other pertinent legislation before the land is used for training purposes. In 2005 and 2006, a Supplemental Environmental Baseline Study was conducted for the Western Expansion Area and reported there were forty-eight known abandoned mining sites within the expansion areas. These forty-eight sites were thought to include 34 shafts, 22 adits, and 14 prospects that would form the primary focus of the hazard assessment portion of this effort. Ultimately, the field team identified an additional twenty mining sites, for a total of 52 adits, 62 vertical shafts, 3 trenches, and 30 prospects or prospect pits; all of which were evaluated.

Similarly, at the time the Environmental Baseline Study was conducted for the East Gate Expansion Area, it was reported there were ten known mining sites within the approximately 45,000 acres (18,212 ha) of withdrawn land, including one that was still active and nine that qualified as abandoned. These ten sites were thought to include 25 shafts, prospects, leaching pits, and related excavations that were the primary focus of the hazard assessment portion of this effort. Ultimately, the field team identified an additional twelve mines, for a total of 18 adits/shafts, 20 prospect pits, 3 leach pits, 7 surface mines 2 prospect trenches, and 1 borrow pit; all of which were evaluated.

Field Investigations

From the outset, it was clear that historic records of mine workings were incomplete and inaccurate. Mine openings were often hidden from view and even relatively close surveillance from an aerial platform did not provide a complete inventory of the features that were of interest. The most reliable source proved to be U.S. Geological Survey quadrangle maps onto which many of the historic mine operations have been marked. The quadrangle maps were used to supplement, and in some cases correct field notes from which the areas of study were determined. Even then, once in the field, the team would investigate old traces and other signs of activity to find satellite workings and prospects that had not been designated in the initial efforts.

Given the remote nature of the NTC expansion areas and the lack of viable roads, much of the work was conducted through the aid of a global positioning system (GPS) and a pair of rugged hiking boots. Teams of two or three field investigators would select a target mining area for the day with specific target mines, and then let their observations expand the search until they had found all reported workings and any unreported workings encountered along the way. It was the latter that nearly doubled the number of workings ultimately mapped and assessed in both the East Gate and Western Expansion Areas.

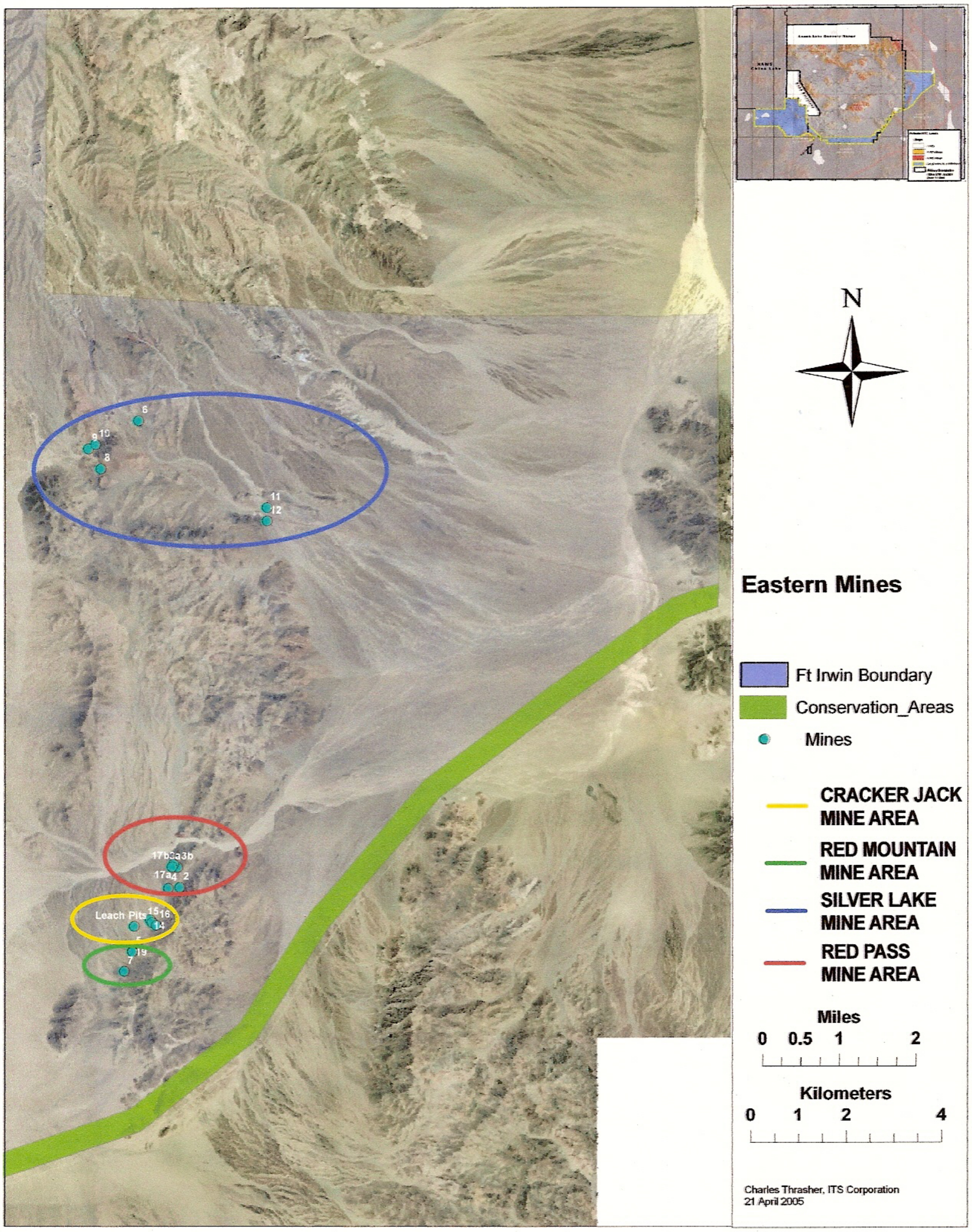
The East Gate Expansion included four discrete mining areas within the overall parcel: the Crackerjack , Red Pass Mine, Red Pass Mountain, and Silver Lakes Mining Areas (Figure 1). The first three areas contained shafts, adits, and prospects related to silver and gold deposits, while the fourth contained surface mines developed around iron ore deposits. The Western Expansion included six mining areas within the overall parcel: Echo, Goldstone, Montana, Rio Hondo, Turquoise, and Uncle Sam Mining Areas (Figure 2). Most of the mining activity in the Western Expansion was related to gold deposits except in the Turquoise Mining Area where turquoise was the primary mineral of interest. Additionally, a small number of mines may have been related to silver deposits and one mine was developed to exploit a titanium deposit. Given the nature of the host rock and the ores being exploited, the primary focus of the team with respect to chemical hazards were arsenic, cyanide, lead, mercury, and selenium. Given the nature of the analytical method employed for metals, results are also obtained for barium, chromium, chromium, and silver. In addition, pH was monitored to determine the potential for acid mine drainage development.

Upon arrival at a mine site, the team would conduct a quick visual surveillance to inventory all workings and mark the GPS coordinates of any significant features or landmarks. A map of the mine site would be prepared to illustrate the relative position of key features within the site and any nearby site. In some cases, processing areas (leach pads, bunkers, tailing piles, etc.) were common to multiple workings. Digital photos were taken to further document anything of significance such as physical hazards and changes in ore characteristics as represented by color or texture.

The team carried a field portable Thermo Niton series XL 700 x-ray fluorescence (XRF) instrument for measuring total metal content. Bulbs were carried for the four primary metals (lead and mercury) and metalloids (arsenic and selenium) of interest. Every attempt was made to identify an outcrop of the parent ore body or otherwise undisturbed rock for the purposes of determining the range of background mineral concentrations. In some cases, the walls of the adit provided an exposed vein that served the purpose of representing background conditions. In other cases, tailings and surface rock were used to designate background. However, under no circumstances were investigators allowed to enter the shafts. As such, the suite of background samples was not as complete as would be desired (e.g., many of the workings are abandoned because the economic ore body was exhausted, leaving no parent ore body with the same mineral content as that from which the predominant tailings were derived. Matched soil and tailing samples were collected of background materials for analysis in certified laboratory, thereby producing a series of coupled samples to calibrate the XRF readings.

The XRF readings were also taken of tailings materials. Whenever elevated levels were observed relative to preliminary remediation goals (PRG) for Environmental Protection Agency (EPA) Region 9 or the background samples, discrete samples were collected for confirmatory analysis in the laboratory. In all, 196 XRF readings were taken and 55 discrete soil samples were collected for laboratory analysis. At the conclusion of the work, the value of the XRF had been fully demonstrated for its application to arsenic and lead despite the presence of significant interferences from high levels of non toxic minerals such as iron (Figures 3 and 4). While outliers were noted, they were biased toward over prediction by the XRF unit, thus causing more samples to be collected for laboratory analysis, rather than less. The correlations for mercury and selenium were not nearly as reliable. However, all concentrations for those chemicals of

Figure 1. Relative Location of Mine Areas Within the East Gate Expansion Area



CALIBRE Systems — Calibre Systems, 64209 E Grover, West Richland, WA 99353	DES'D: GWD	CLIENT: US Army	PROJECT NO.: LS026000
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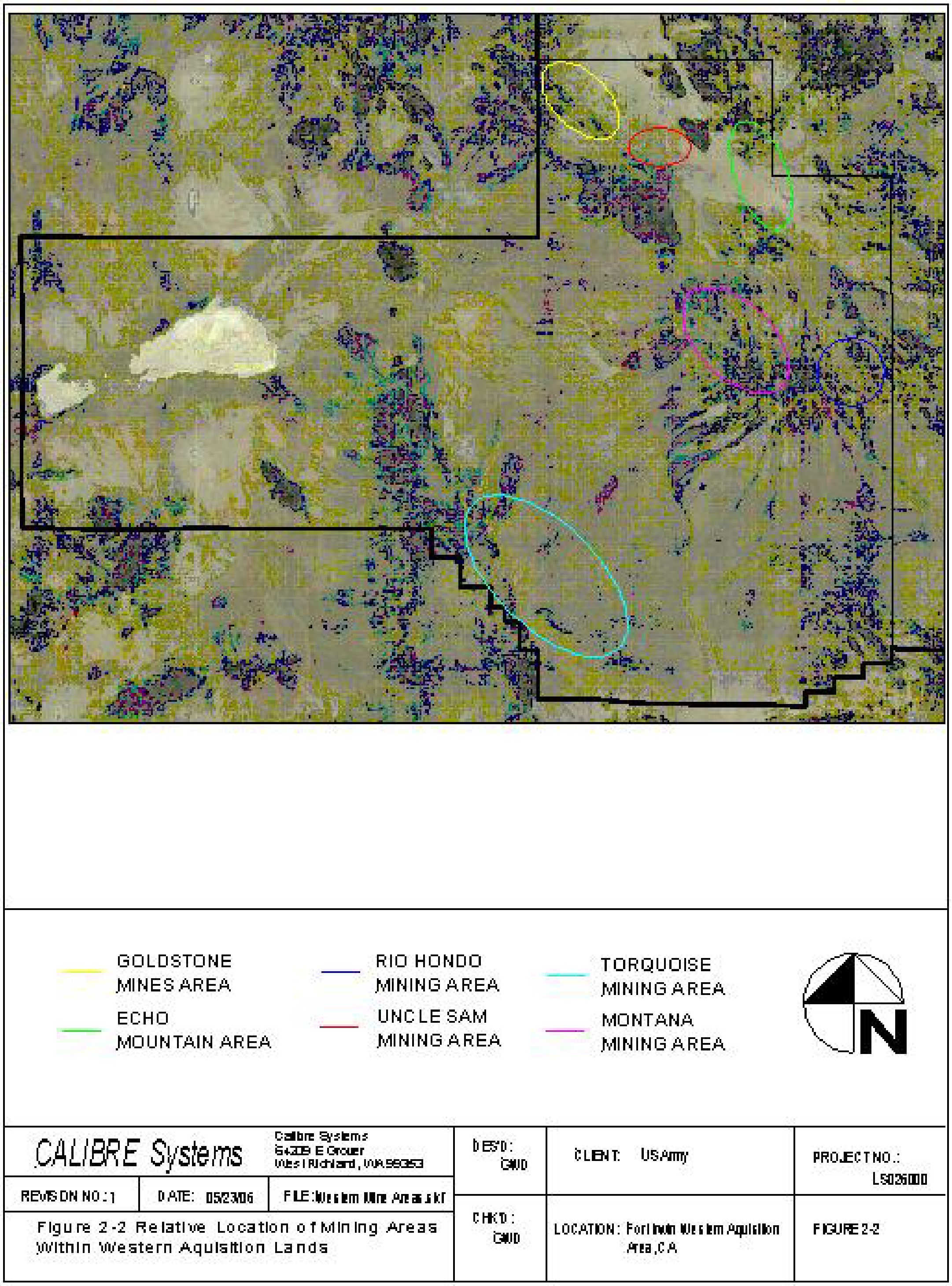
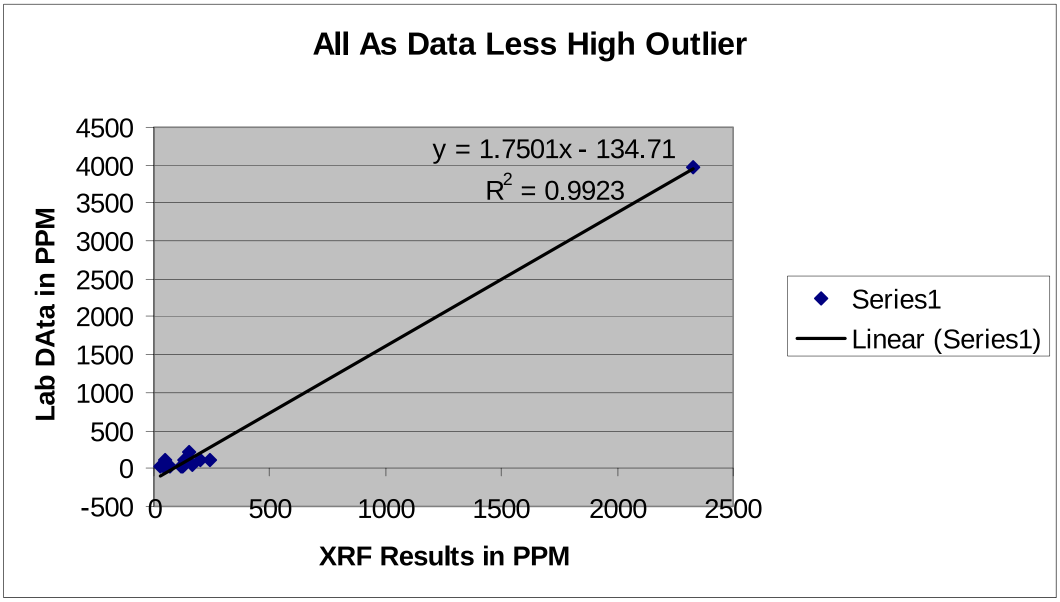
Figure 3-1 Relative Location of Mining Areas Within Eastgate Expansion Lands	CHK'D: GWD	LOCATION: Fort Irwin Eastgate Expansion Area, CA	FIGURE: 3-1

Figure 2. Western Expansion Mining Areas Location Map



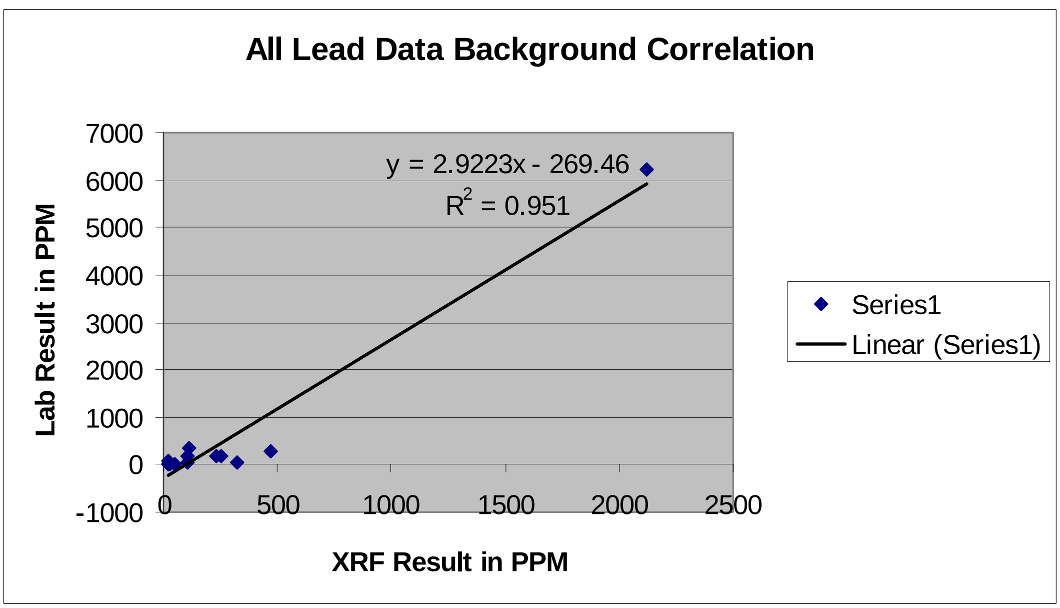
concern were observed to be below PRG values, so the consequences of poorer predictability were not significant.

Figure 3. Relationship Between XRF and Laboratory Results for Arsenic with Outlier Removed



In addition to soil and ore samples, the team collected samples of any media from what appeared to be beneficiation areas (e.g., leach pads or mills), any liquids present (including collected rain water), and any contents of drums or tanks found in tact on the sites. These samples were analyzed for cyanides or petroleum products, as appropriate.

Figure 4. Relationship Between XRF and Laboratory Results for Lead



Chemical Hazards

No results were obtained indicating a significant release of chemicals as a result of mining activities in either expansion area. Minor releases were noted in the form of extremely low levels of cyanide at some precious mineral processing sites, and small areas of petroleum staining in soil around abandoned drums. One drum was found to be partially full of a hydraulic fluid.

This is not to say that chemical hazards are not present at the mine sites. Natural levels of arsenic and lead were observed at extremely high concentrations that could pose an unacceptable risk from direct ingestion under normal risk assessment exposure scenarios. The range for naturally occurring arsenic and lead were found to be up to a maximum value of 4,930 mg/kg and 6,230 mg/kg, respectively. This is consistent with the findings of others. The Mojave Desert mining province of California has historically been mined for base metal deposits (copper, lead, zinc). The productive ores are typically irregular masses of sulfides. The ores commonly contain complex minerals including various base metals, silver, arsenic, antimony, and sulfur. Some of the common arsenic bearing minerals includes:

Arsenopyrite {FeAsS}

Arseniosiderite $\{Ca_2Fe^{3+}{}_3(AsO_4)_3O_3 \cdot 3(H_2O)\}$

Austinite $\{CaZn(AsO_4)(OH)\}$

Sulfide bearing ores have been extensively studied and evaluated in other mining areas of California (e.g., see USGS 1997, USGS 2002, Ashley 1999). In fact, the USGS from 2002 indicates that naturally occurring arsenic is commonly present in sulfide bearing ores in the range of 100 to 10,000 mg/kg.

Clearly, the Army cannot attempt to remove all naturally occurring arsenic and lead that is present in concentrations in excess of risk-based criteria for direct contact under an infrequent exposure scenario. Therefore, the chemical hazard that exists at these sites by virtue of their mineral content is best addressed through institutional controls in the form of training guidelines, training frequencies, and judicious positioning of training exercises outside the mining areas with toxic mineral levels.

All drums and tanks (intact or crushed) were logged in the field notes and identified for removal to prevent their being used for illegal disposal in the future or raising the perception that they may contain hazardous substances, thus triggering further characterization efforts in subsequent years.

Physical Hazards

Four types of physical hazards were noted:

- Open shafts (> 60° angle) with no covers (8);
- Adits of questionable structural integrity (13) that may also contain toxic gases;
- Sheer walls and escarpments (7);
- Unstable surfaces underlain by adits (1);

Shafts (Figure 5), unstable surfaces, and sheer walls (Figure 6) are of particular concern because of the danger they pose to soldiers training in the area, especially when exercises are run at night. The anticipation of training with tanks dramatically increases the weight bearing capacity required for the unstable surfaces in areas where slopes are not too great for tank operations.

The adits (Figure 7) were inventoried both as assets and potential hazards. As a consequence of the conditions under which current military operations are being conducted, there is some interest within the Army to have tunnels and cave-like structures available for training purposes. As such, any adit that was more than 15 feet in length and had an opening at least five foot high was marked for evaluation as a special training area. Supplemental evaluations in the form of structural integrity and air quality testing are planned for any adit deemed of interest for future training.

In addition, to the primary physical hazards, a number of sites were noted to have a variety of debris such as boards with nails (Figure 8). These features were marked for removal or mitigation to reduce the risk of puncture during night training exercises.

Figure 5. Mine WA-63 Shaft

Figure 6. Mine 2b Highwall Trench

Figure 7. Crackerjack #3 Mine

Figure 8. Debris at Red Pass Mine #1

Endangered Species Considerations

There were three principle concerns with respect to endangered species: bats, burrowing owls, and the desert tortoise. In the former case, preliminary surveys confirmed that both bats and burrowing owls were using the vertical and horizontal shafts for habitat. As a consequence, closure of the shafts could sacrifice any individuals of those species in the shafts at the time, and would clearly reduce the overall habitat area for those species. Pursuant to minimizing any impact on either species, a qualified expert was contracted to perform an evaluation of all shafts. Fifty three (53) of the shafts were found to either be in active use or potentially be in use by bats or burrowing owls. For those shafts with habitat implications that are not retained for training, provisions will be necessary to allow for ingress and egress of bats and owls after closure.

With regards to the desert tortoise, it was observed that prospect pits too shallow to pose a threat to soldiers could act as a trap for these endangered animals. Many of the pits were found to have sheer walls that the tortoise can not surmount if it happens to fall in. The field team observed one tortoise dead in such a prospect and rescued a second that was similarly trapped, but still alive (Figure 9). In response to this discovery, a fifth hazard type was created: pits that could act as tortoise traps.

Figure 9. Desert Tortoise Trapped in Prospect Pit

Closure Designs

Three levels of response were developed to address the physical hazards:

1. Temporary access restrictions in the form of fencing or tank barriers;
2. Designs promoted by the American Cave Conservation Association (ACCA); and
3. Permanent closure using an innovative new design to reduce costs.

Temporary fencing can be as simple as a three strand wire configuration such as was encountered at one of the sites (Figure 10) or a more challenging design using three rolls of concertina in a pyramid configuration (Attachment A). Fencing of either design is recommended when the ultimate nature of use or design of final closure is still undecided. As an example, some of the remote mines had not had an official bat survey conducted at the time that access restrictions were needed. Similarly, when expensive closure designs were appropriate, budget constraints could necessitate temporary closure until funds are available.

The ACCA designs are based on the realization that over time, individuals will attempt to break into the mines left on public properties with a variety of aids such as hack saws and

Figure 10. Barbed Wire Fence Around Shaft at Mine WA-32a

wrecking bars. Consequently, they call for an extremely robust closure design that calls for reinforced four-inch steel angle iron struts and slats set in reinforced concrete (Attachment B).

The third tier of designs was developed with the specific application at the NTC in mind. Because the mines are present in an active military training range with security provisions, it was posited that trespassers were not likely. The most likely individual to try to enter the closed mines will be a soldier in training who will have access to powerful means of breaching containment (hand grenades and automatic weapons) if truly determined to enter. Therefore, the design should frustrate casual attempts at entry, but not contemplate foiling a committed effort. Moreover, budget considerations and the need to haul materials into remote areas without road access suggested selection of lighter weight materials. In the end, modular designs were developed to accommodate easy transport onto sites and subsequent assembly. Features were added to thwart use of hack saws. Once completed, it was felt that these designs offer an alternative to the ACCA designs that should be evaluated for non military sites because of their savings potential (Attachment C).

The Army is now evaluating the blend of barriers and institutional controls that provide the best overall protection for the planned use of the properties going forward. Costs per mine of the designs range up to $20,000 depending on the provisions for bats and the degree of forced entry that is to be denied. A detailed cost comparison of each hazard type has been provided. A summary of approximate costs for each option for the different hazard types is provided in Table 1.

Table 1. Comparison of Estimated Closure Costs

Hazard Type	Fencing	ACCA Design	CALIBRE Design
Vertical Shaft	$500	$20,000	$10,000
Adit	$500	$8,000	$1,500
High Wall	$1,500	NA	NA
Unstable Surface	$1,000	NA	$1,500

Data Management

In addition, all spatial and attribute information for expansion lands is being incorporated as a spatial data layer in the Fort Irwin & NTC Geographic Information System geodatabase and within the Army's Operational Range Inventory (ORI). The ORI was initiated in response to increasing environmental and regulatory pressures on Army ranges and training areas, and reporting requirements from Senate Report 160-5 and Department of Defense Directives (DoDD) 4715.11 and 4715.12. As there are nearly 500 Army installations and training sites worldwide, the updates occur on a repeatable schedule and the information is stored in the Army Range Inventory geodatabase (ARID-GEO). The Operational Range Inventory provides the Army with unparalleled availability of information on its training assets and supports many users in the Sustainable Range Program.

Because the data are standardized across all installations and states, the number of data calls is significantly reduced and decision makers have information readily accessible. Additionally, the data are more readily transferred to various management systems, significantly reducing the amount of operator time/effort and keystroke errors.

References

Ashley, R. P., 1999, Historical gold mining in California and its environmental consequences: AAAS Annual Meeting and Science Innovation Exposition, Challenges for a New Century, 21-26 January, Anaheim, California,.

USGS 2002 Progress on Geoenvironmental Models for Selected Mineral Deposit Types, U.S. Geological Survey Open-File Report 02-195

USGS 1997, Environmental geochemistry of gold deposits in the Mother Lode Belt, California, in Wanty, R.B., Marsh, S.P., and Gough, L.P., eds., 4th International Symposium on Environmental Geochemistry, Program with Abstracts: U.S. Geological Survey Open File Report 97-496

Attachment A.
Fencing Design Specification and Depiction

Fencing design to prevent soldiers from free access to the individual mine openings and/or mine complexes will consist of three double-coil 38 inch in diameter concertina wire. These concertina coils are specifically designed to provide maximum perimeter barrier protection and security. They will be pyramided (Figure C-1) and the pyramid shape will be secured with a tie (Figure C-2) every 5 feet at the contact point of all three rows. The concertina coils will be affixed to the ground every 10 feet by 18-inch "J" shaped ground stakes (Figure C-3.).

In locations where there is vehicular access, rubber tired or tracked, (less than 30% slope) four-foot berms will be constructed.

Figure A-1. Pyramided Concertinas

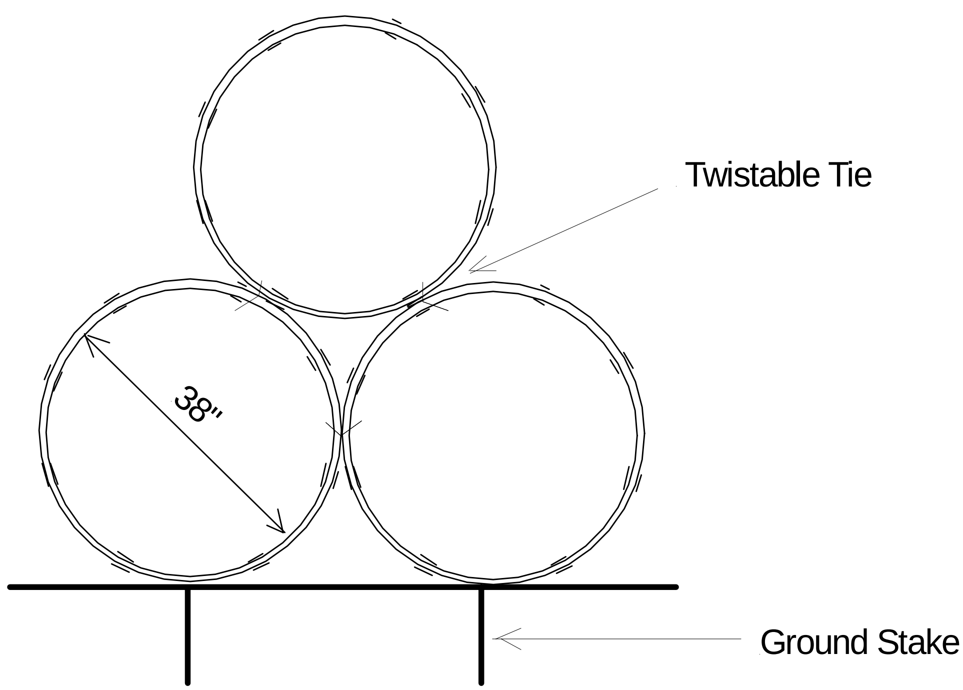


Figure A-2. Twistable Wire Tie

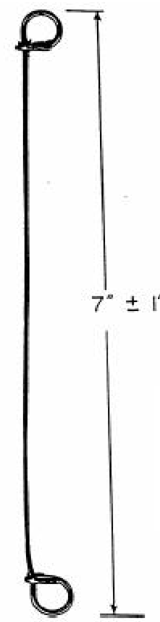
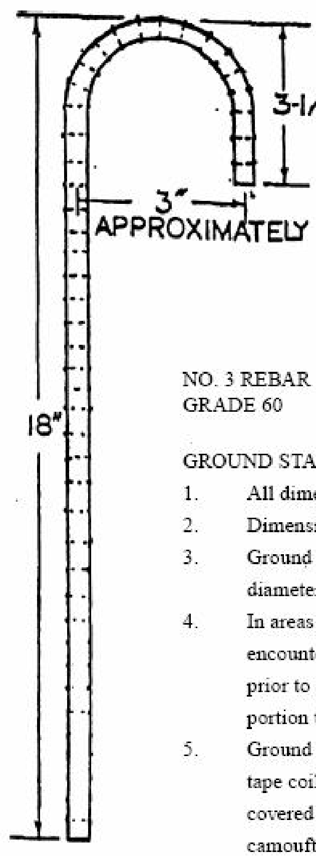


Figure A-3. Ground Stakes



NO. 3 REBAR
GRADE 60

GROUND STAKES

1. All dimensions are in inches.
2. Dimensional tolerances are +/- 1.0 inches.
3. Ground stakes are fabricated from 3/8" diameter concrete reinforcing bar, grade 60.
4. In areas where hard clay or rock is encountered, pilot the hole at least 12" deep prior to inserting stake. Drive the remaining portion to its full depth.
5. Ground stake hooks will encompass barbed tape coils on the ground. Stakes should be covered with gravel, crushed stone, or dirt to camouflage their location.

Attachment B.

American Cave Conservation Association Design Specifications and Depictions

The following plans are provided courtesy of the American Cave Conservation Association and are revised annually. The plans depict the construction and emplacement of bat gates designed to meet American Cave Conservation Association specifications.

The mine closure designs will be custom built on site in accordance with the generic design specification.

Reference: Bats and Mines by Merlin D. Tuttle and Daniel A. R. Taylor of Bat Conservation International, Inc., Appendix III, 1998 as supplied by American Cave Conservation Association.

Figure B-1. Typical Bat Gate Design A

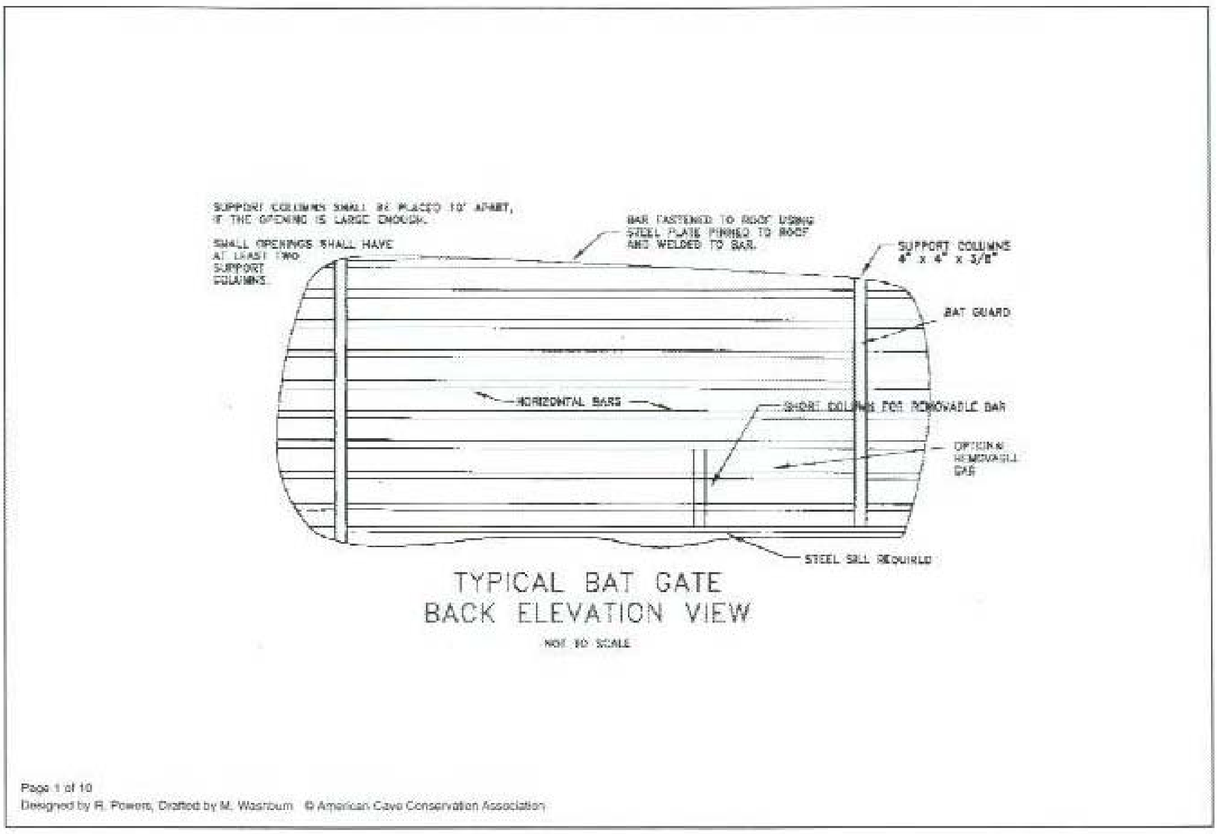


Figure B-2. Typical Bat Cupola Design A1

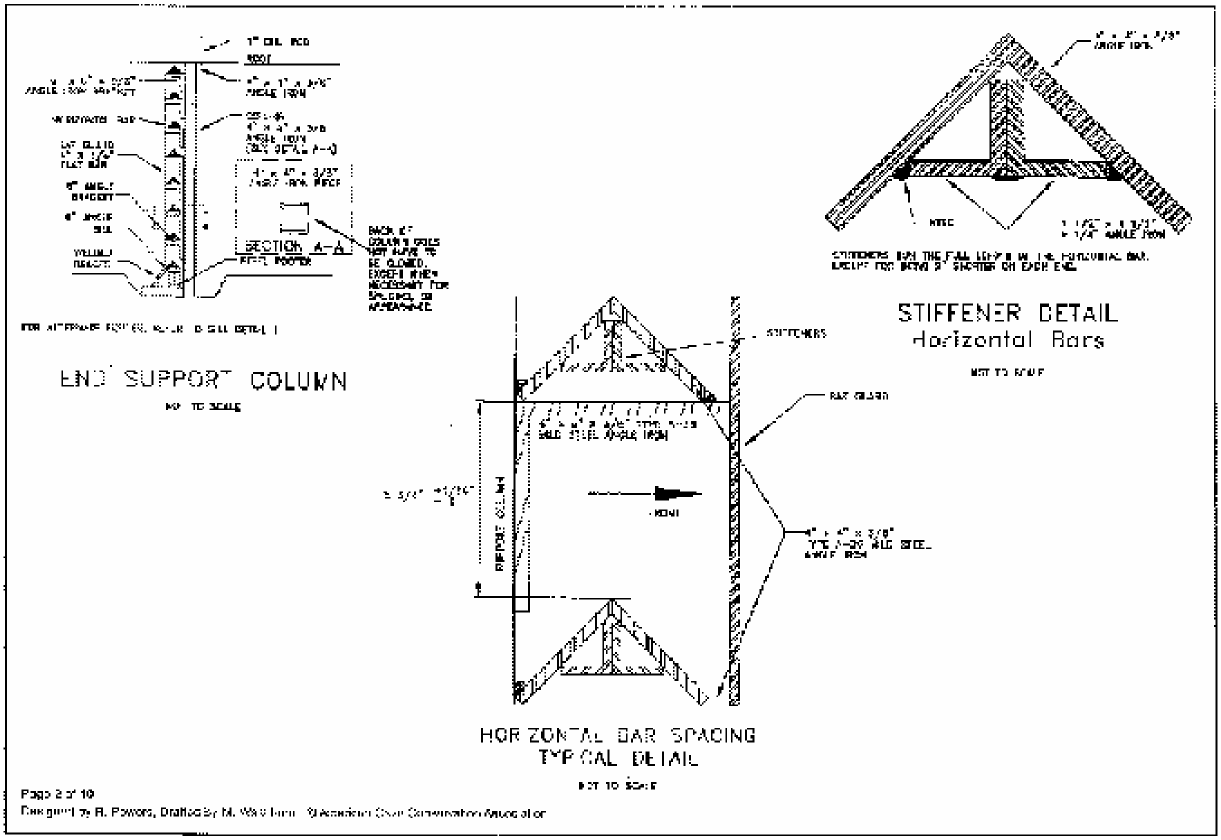


Figure B-3. Typical Bat Cupola Design A2

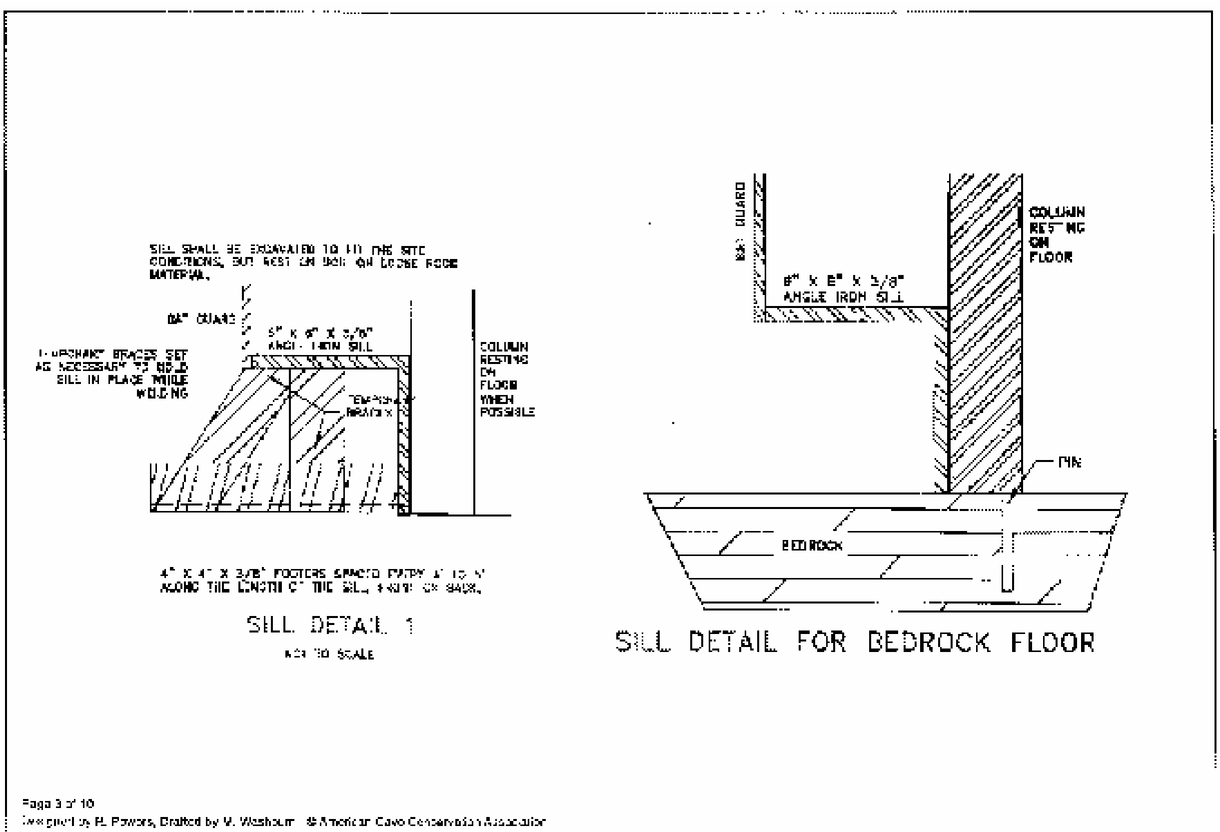
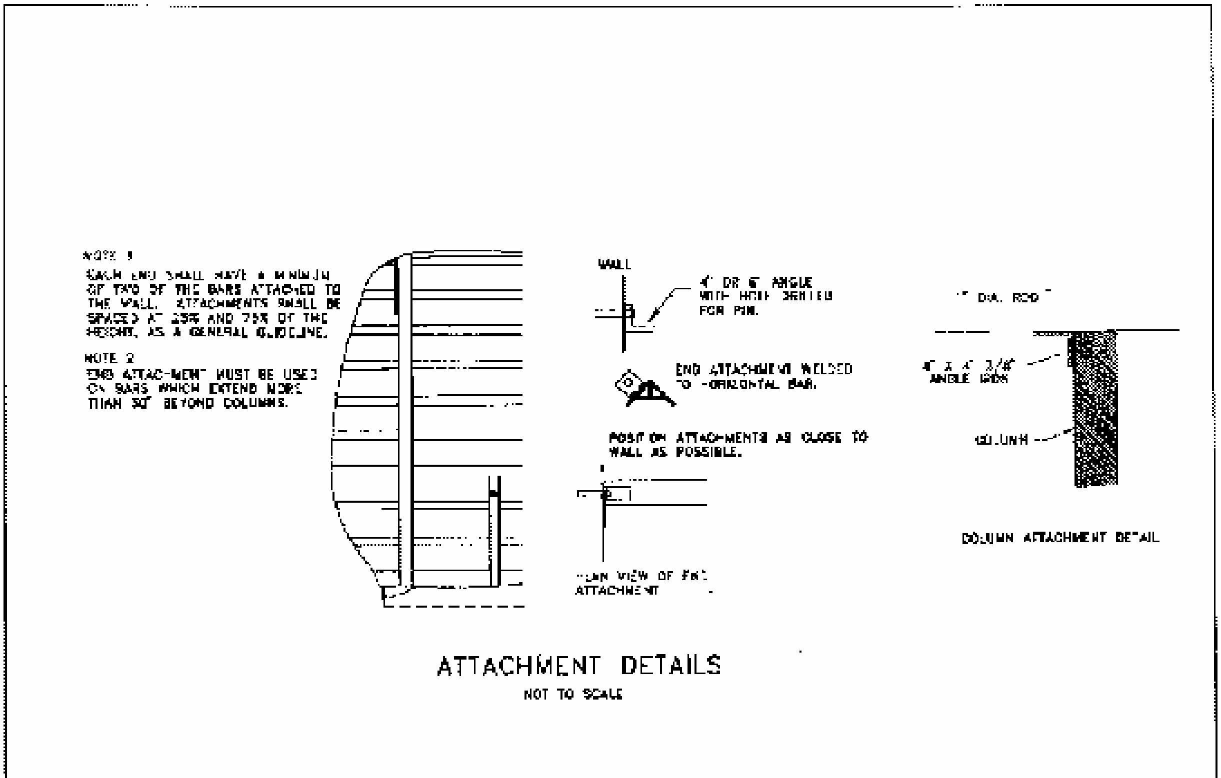


Figure B-4. Typical Bat Cupola Design A3



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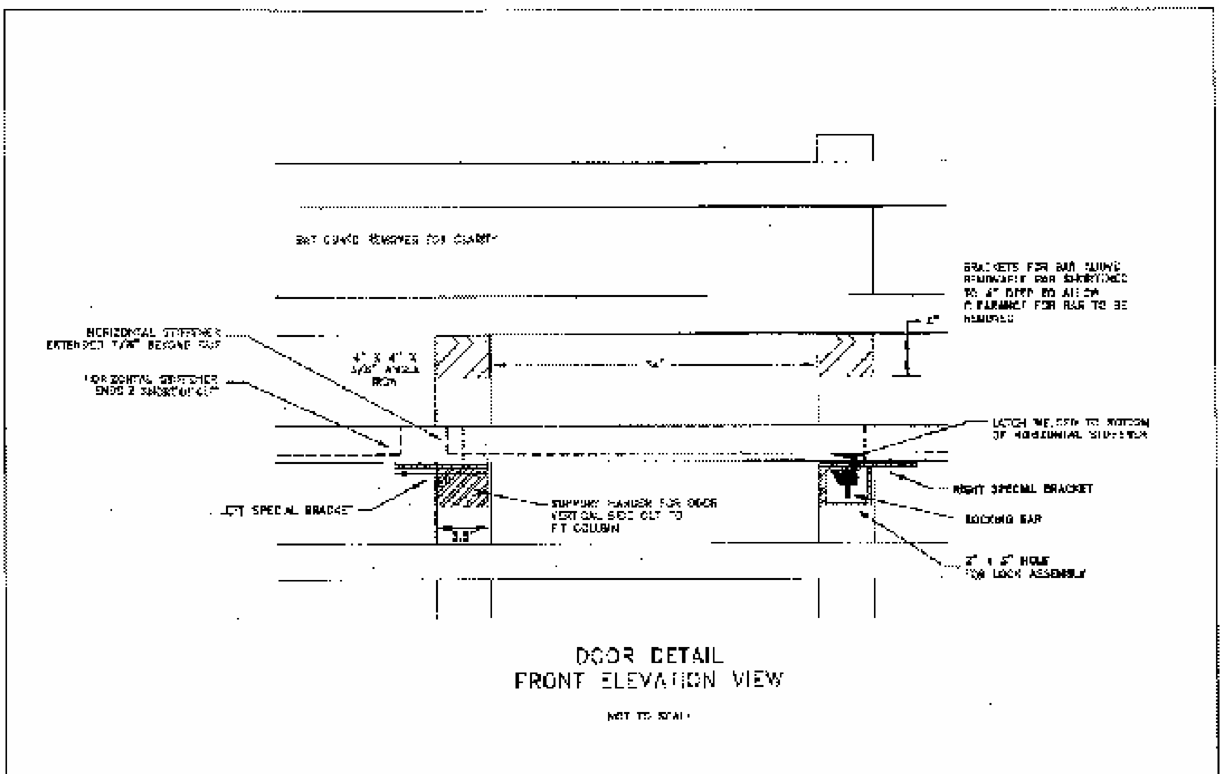
Designed by R. Powers. Drafted by M. Washburn. ©American Cave Conservation Association

Figure B-5. Typical Bat Cupola Design A4



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Designed by R. Powers. Drafted by M. Washburn. ©American Cave Conservation Association

Figure B-6. Typical Bat Cupola Design A5

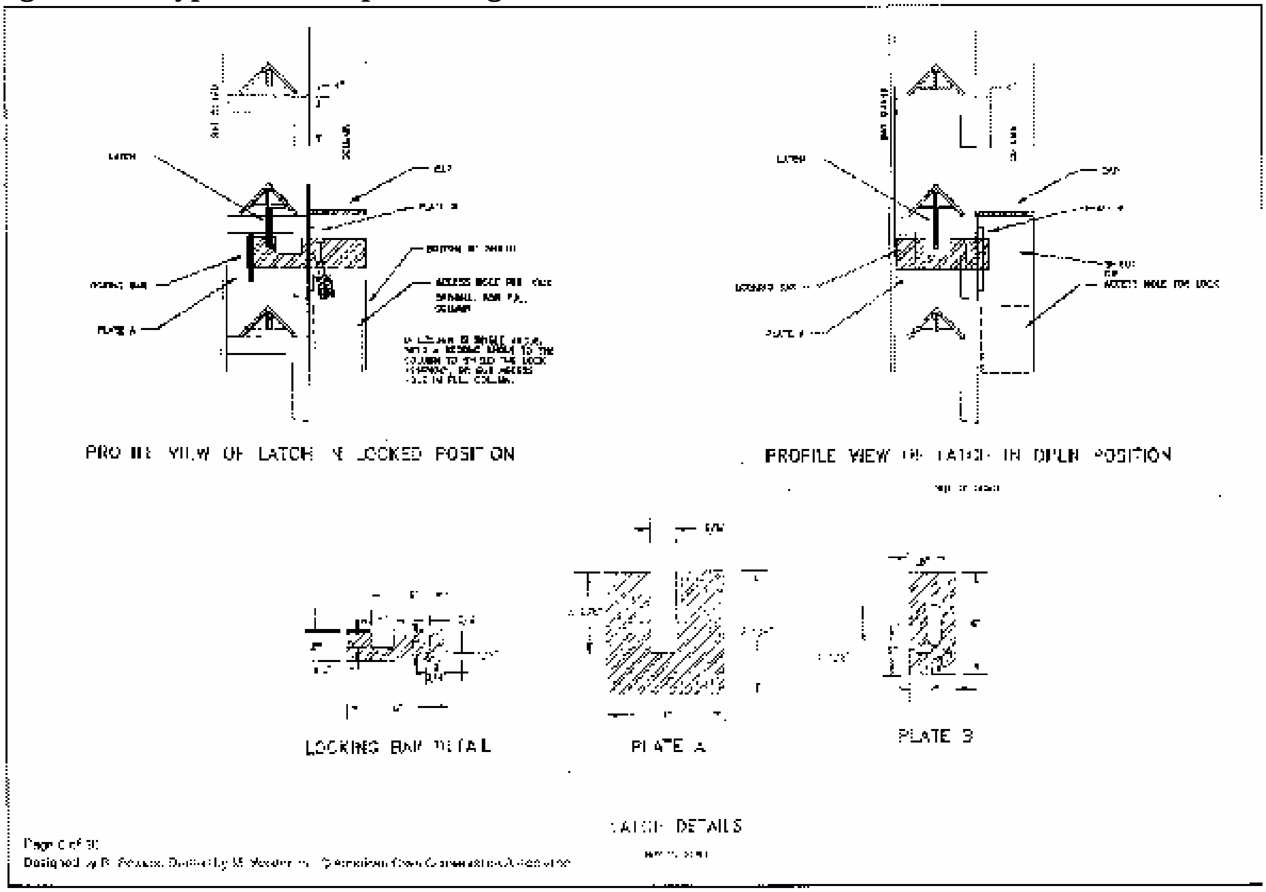


Figure B-7. Typical Bat Cupola Design A6

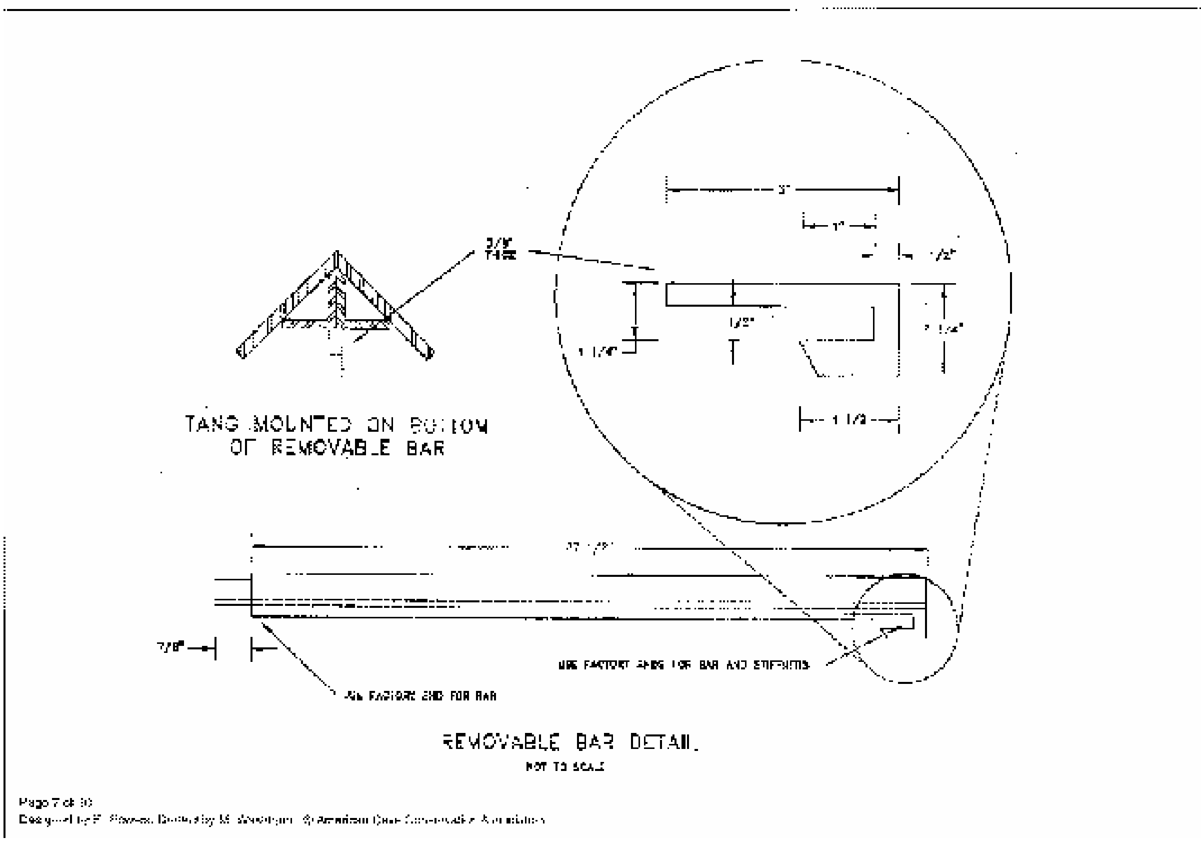


Figure B-8. Typical Bat Cupola Design A7

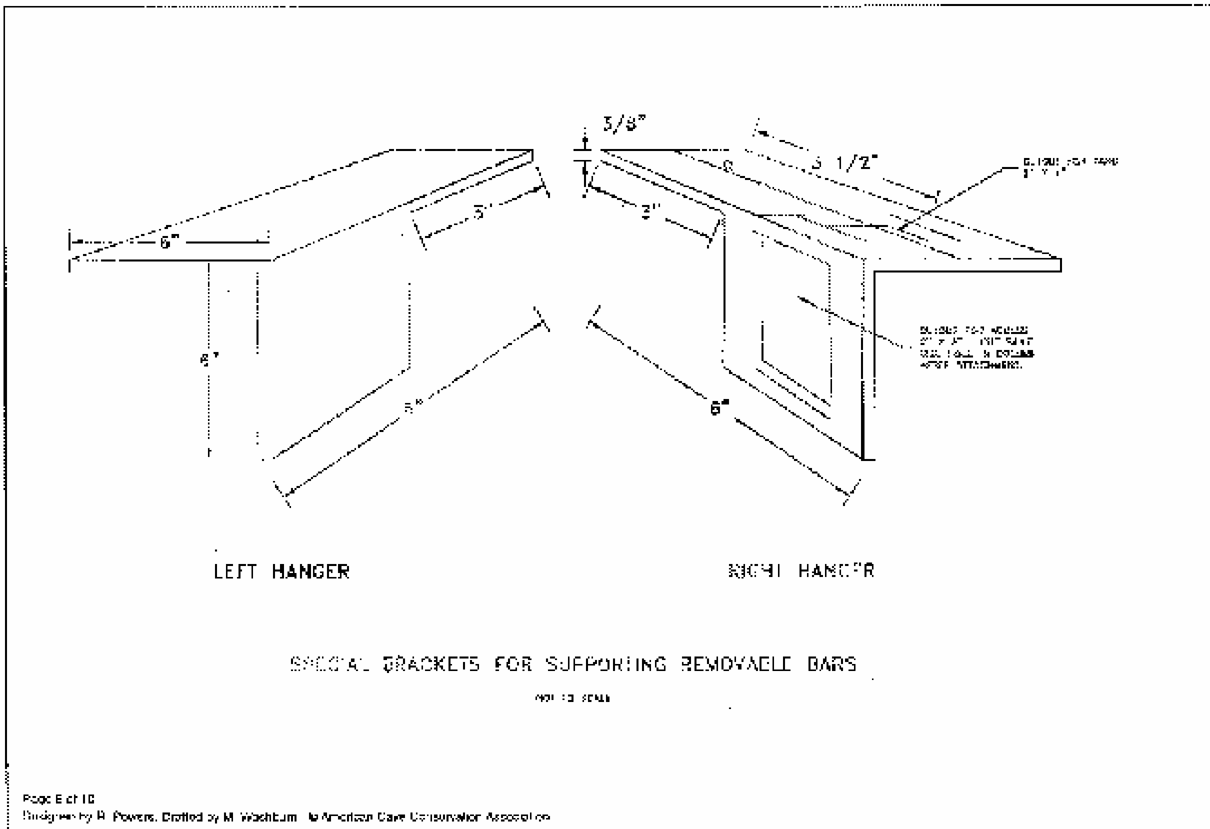


Figure B-9. Typical Bat Cupola Design A8

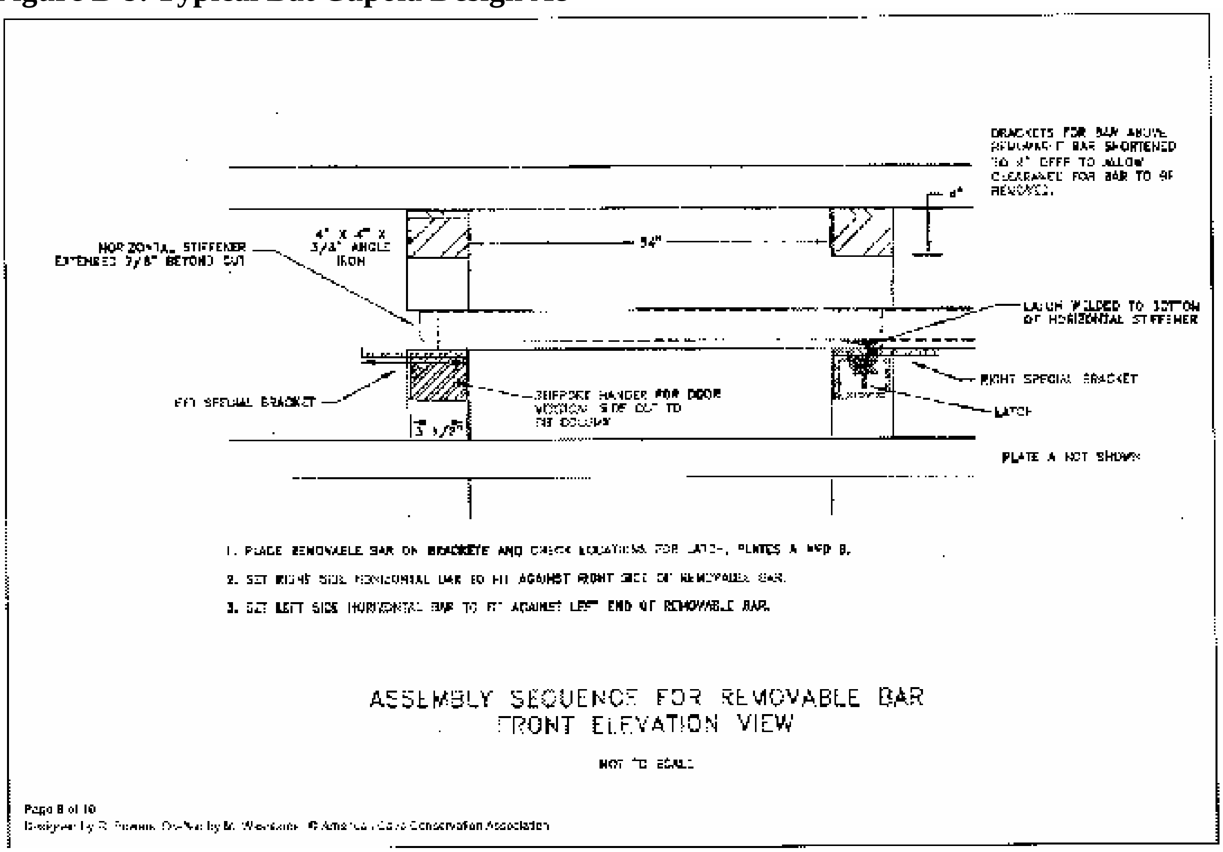


Figure B-10. Typical Bat Cupola Design A9

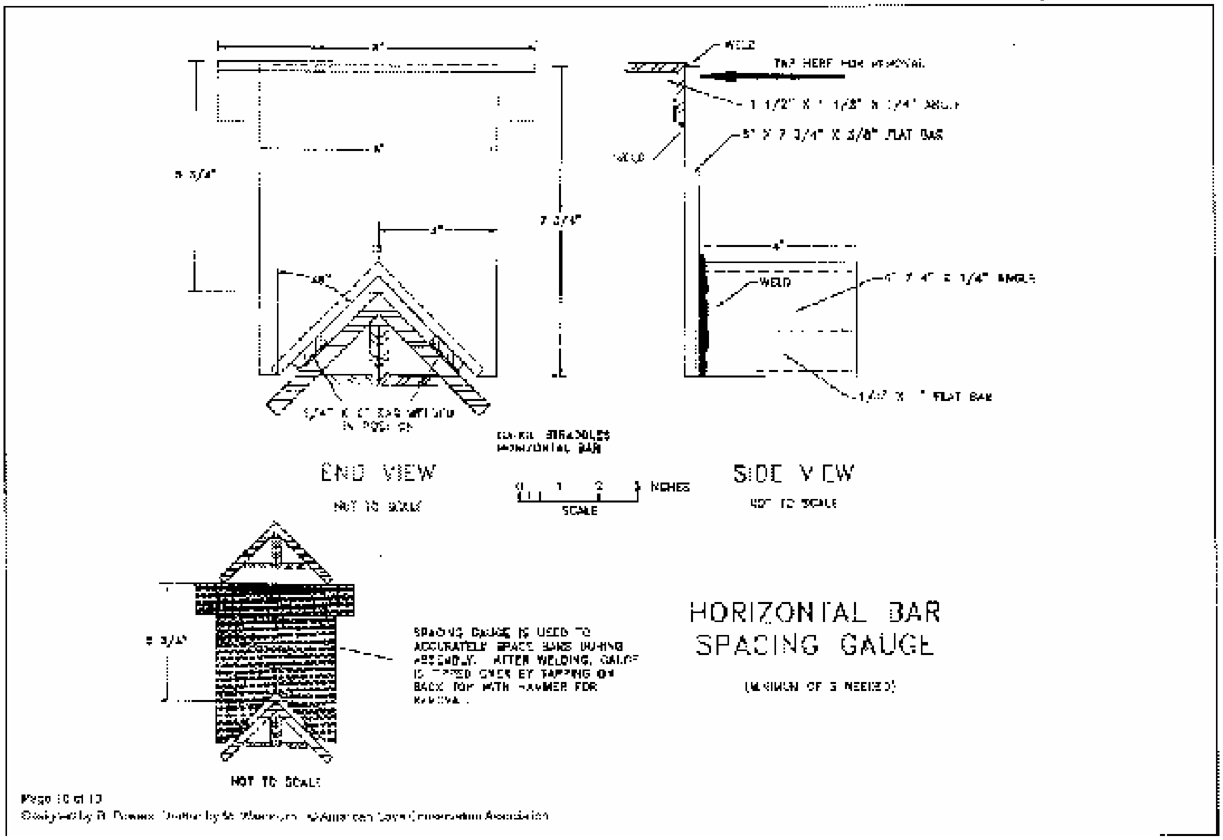


Figure B-11. Typical Bat Gate Design B1

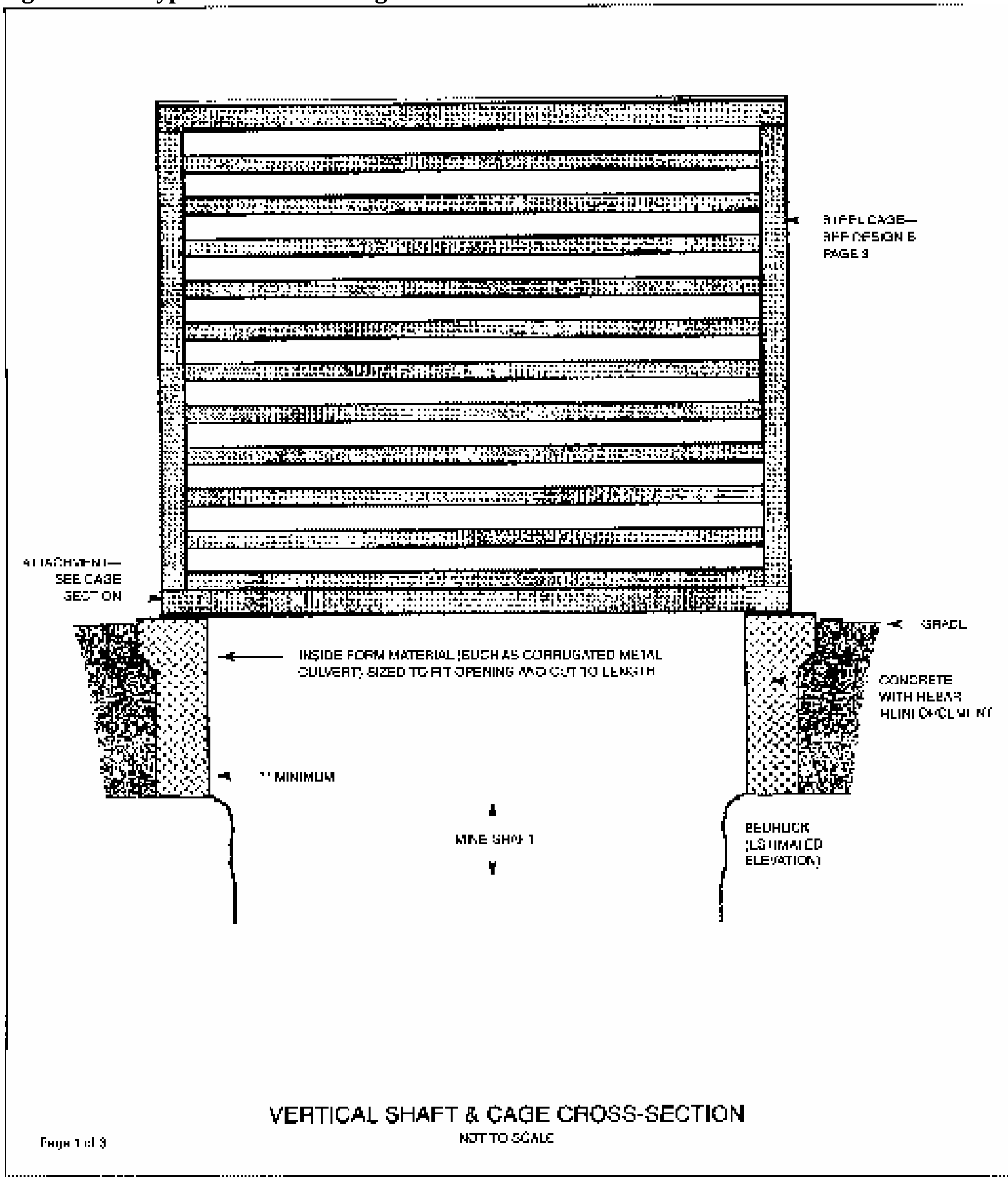


Figure B-12. Typical Bat Gate Design B2

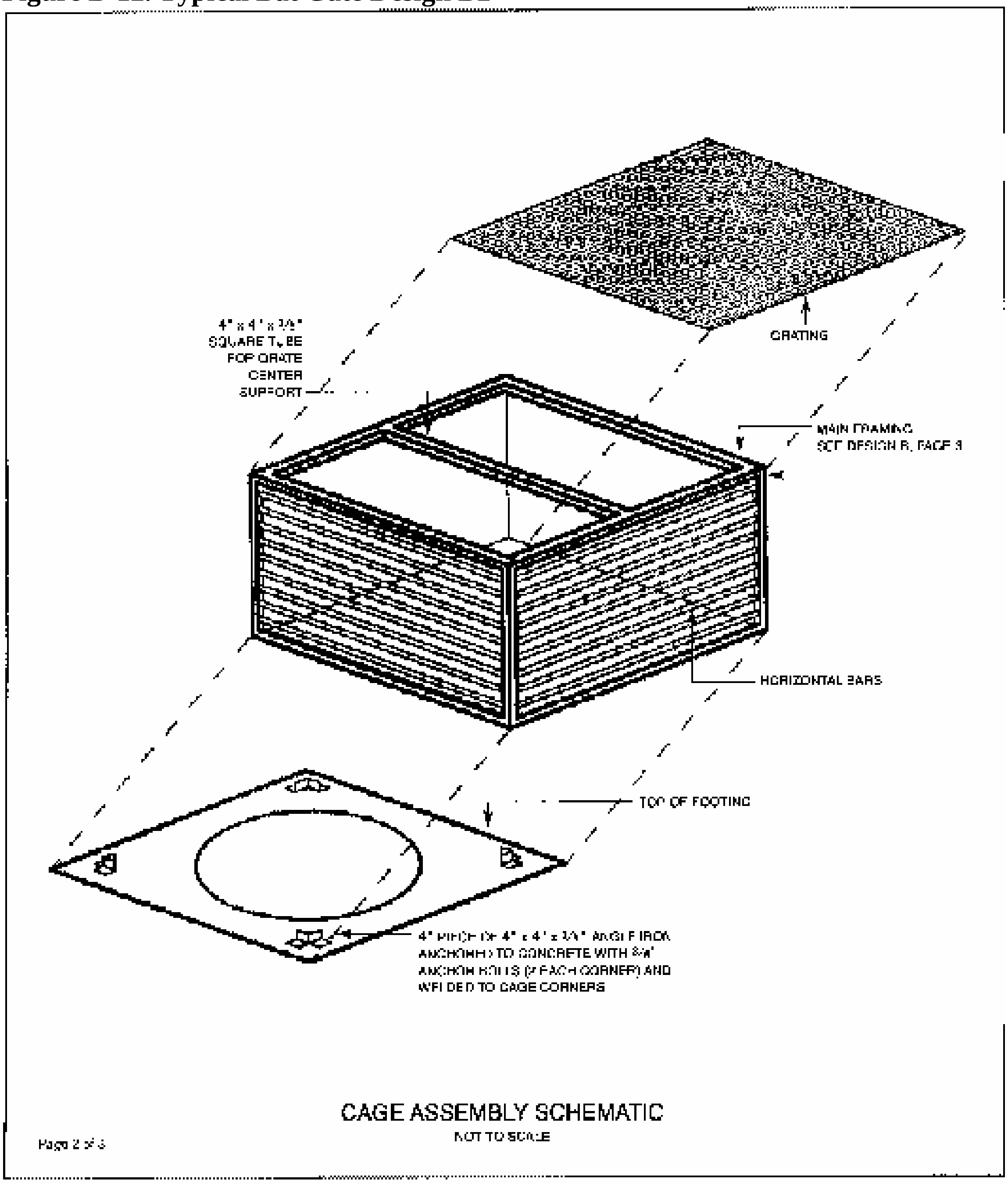
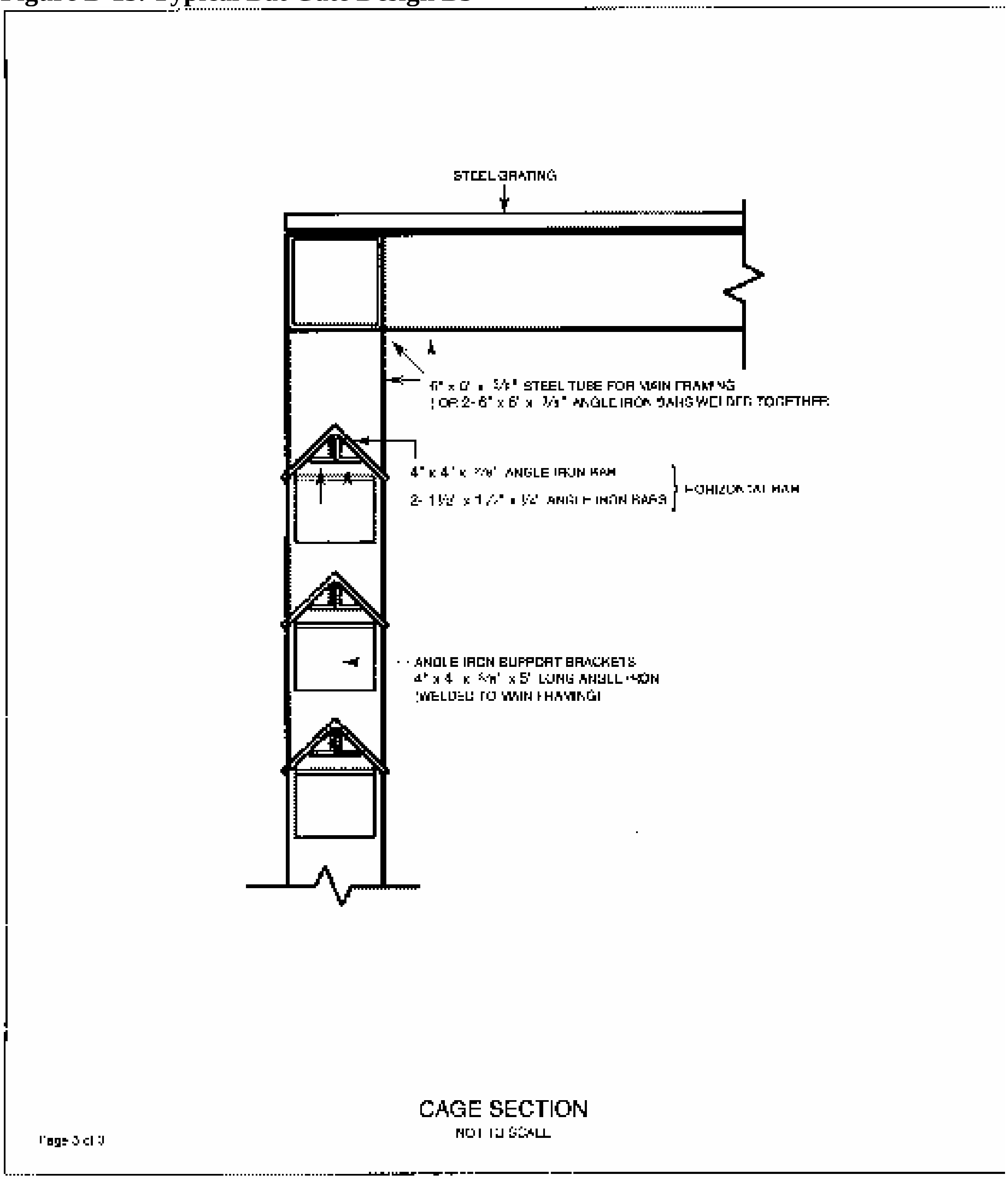


Figure B-13. Typical Bat Gate Design B3



Attachment C.
Modular Bat Grate and Bat Culvert Design Specifications and Depictions

An alternative method for ACCA closure of shafts with provision for bats ingress and egress is to use a modular bat grate design. This design also meets the requirements for burrowing owl ingress and egress. Figure C-1 illustrates the construction of each aluminum grate and demonstrates the method of allowing for bat access. The mine closure grate is constructed from expanded steel mesh and a number of aluminum modular panels of which 2 are arranged to allow bat access as shown in Figure C-2. A number of anchor pins are used to fasten the assembled grate to the ground surface. Each anchor pin is driven 18-inches into the ground surface to provide adequate support and prevent removal of the grate from any but a concerted effort. The amount of hardware needed for closure of individual shafts is itemized in Table B-1 of this attachment.

An alternative method of closing the adit openings to humans, but allowing for bat entrance is to use a bat culvert, illustrated in Figure C-3. This design also meets the requirements for burrowing owl ingress and egress. An eight-foot long steel culvert is placed at a slight angle into the adit opening; a constructed grate is then bolted over the exposed opening allowing for bat or burrowing owl ingress and egress. To hold the culvert in place, an 18-inch spike is driven into the ground surface through a bolt hole near the exposed entrance of the culvert. Once the culvert is in place the opening of the adit is collapsed around the culvert closing the opening and preventing access without a concerted effort. A four-foot section of six-inch culvert is inserted at the top of the entrance fill to promote air circulation in the bat and burrowing owl habitat area.

Figure C-1. Example of Aluminum Grate Design and Bat Shaft Gate

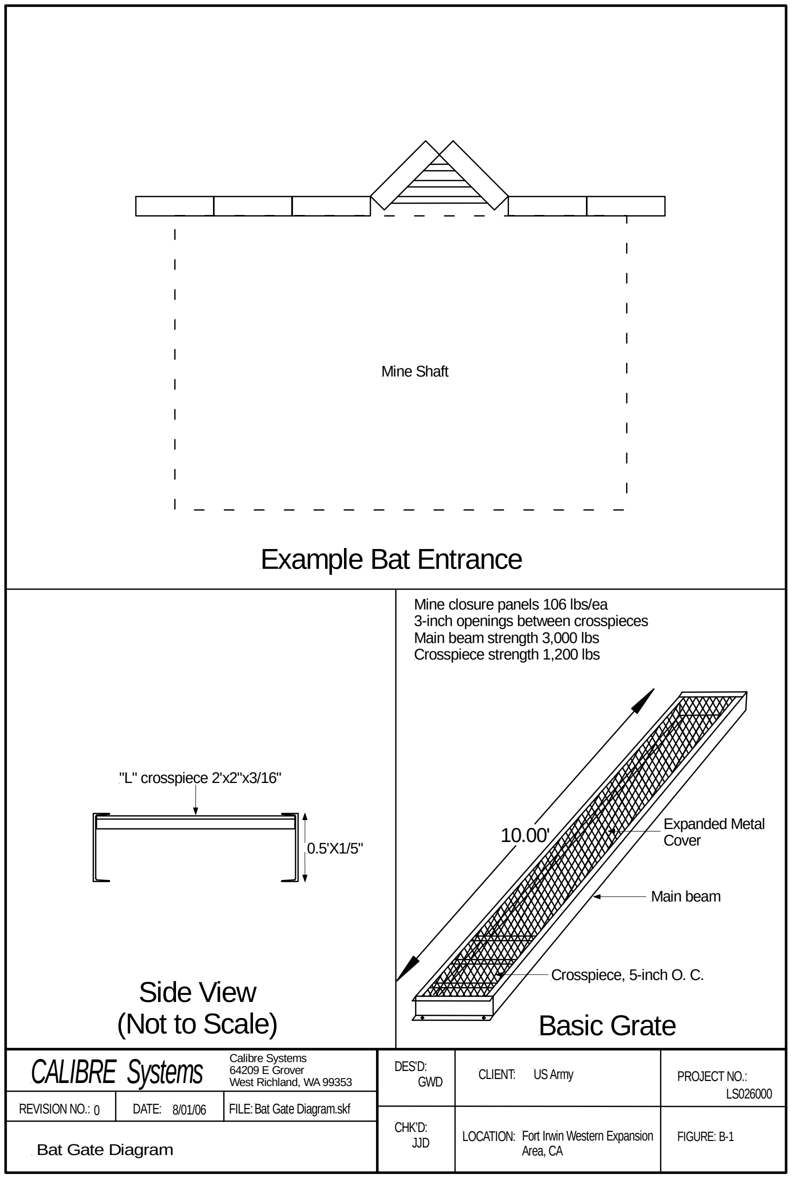


Figure C-2. Example of Bat Gate Over the Shaft and System of Anchoring

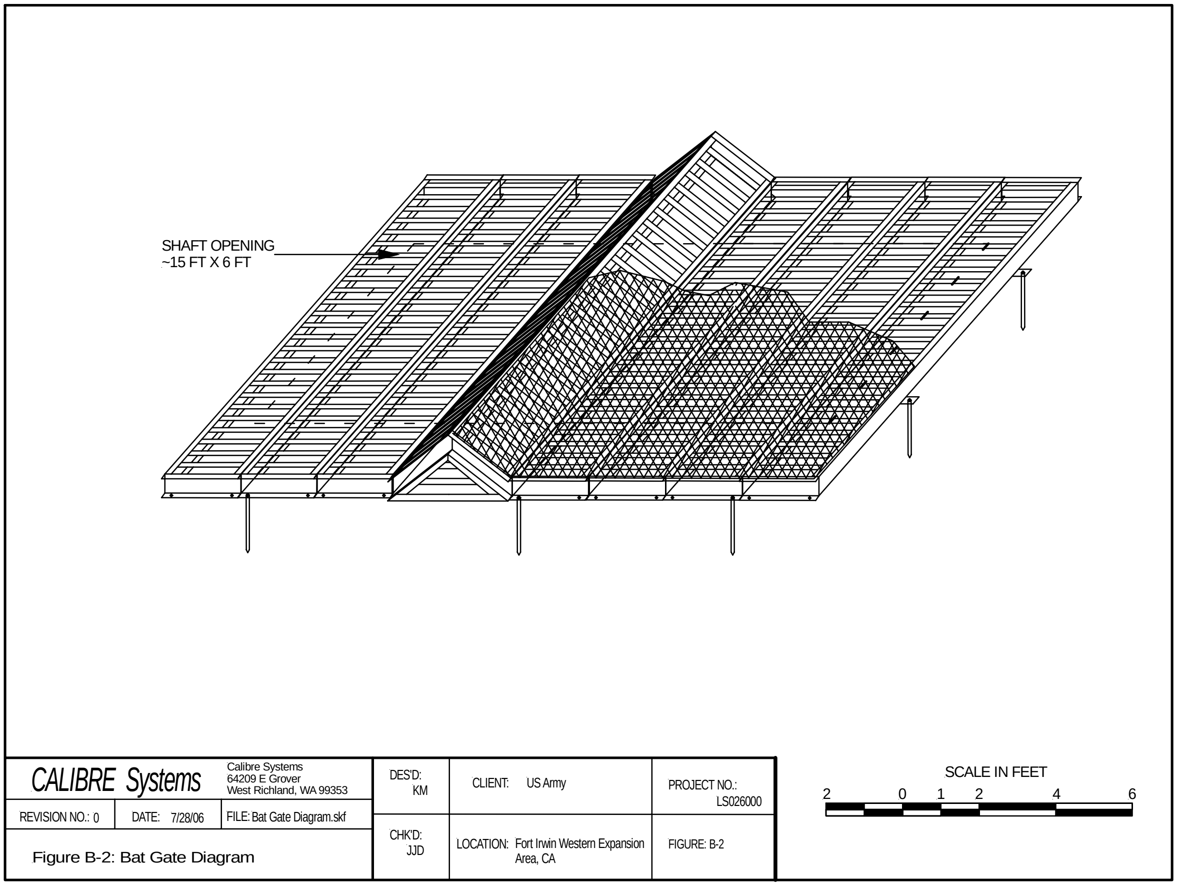


Figure C-3. Example of Culvert Installation and Specifications